



## **A method of detecting a structure in a field, a method of steering an agricultural vehicle and an agricultural vehicle**

**Rufus Blas, Morten; Blanke, Mogens; Madsen, Tommy Ertbølle**

*Publication date:*  
2011

*Document Version*  
Publisher's PDF, also known as Version of record

[Link back to DTU Orbit](#)

*Citation (APA):*  
Rufus Blas, M., Blanke, M., & Madsen, T. E. (2011). A method of detecting a structure in a field, a method of steering an agricultural vehicle and an agricultural vehicle.

---

### **General rights**

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

(19)



(11)

**EP 2 368 419 B1**

(12)

**EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention  
of the grant of the patent:  
**10.08.2016 Bulletin 2016/32**

(51) Int Cl.:  
**A01F 15/08 (2006.01) A01B 69/00 (2006.01)**

(21) Application number: **10157313.7**

(22) Date of filing: **23.03.2010**

(54) **A method of detecting a structure in a field, a method of steering an agricultural vehicle and an agricultural vehicle**

Verfahren zur Erkennung einer Struktur auf einem Feld, Verfahren zum Lenken eines  
landwirtschaftlichen Fahrzeugs und ein landwirtschaftliches Fahrzeug

Procédé pour détecter une structure dans un champ, procédé de direction d'un véhicule agricole et  
véhicule agricole

(84) Designated Contracting States:  
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR  
HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL  
PT RO SE SI SK SM TR**  
Designated Extension States:  
**AL BA ME RS**

(43) Date of publication of application:  
**28.09.2011 Bulletin 2011/39**

(73) Proprietor: **CLAAS E-Systems KGaA mbH & Co KG  
33330 Gütersloh (DE)**

(72) Inventors:  
• **Blas, Morten Rufus  
2200, Copenhagen N (DK)**

• **Blanke, Mogens  
3520, FARUM (DK)**  
• **Madsen, Tommy Ertbølle  
2830, Virum (DK)**

(74) Representative: **Belda, Stefan Johannes et al  
CLAAS KGaA mbH  
Patentabteilung  
Münsterstraße 33  
33428 Harsewinkel (DE)**

(56) References cited:  
**EP-A1- 1 529 428 EP-A1- 1 738 630  
EP-A2- 0 887 660 WO-A1-2007/031093**

**EP 2 368 419 B1**

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

**Description**

**[0001]** The present invention relates to a method of detecting a structure in a field, said method comprising: providing an image of the field, analysing the image to obtain texture information, assigning to a plurality of areas of the image probability-values reflecting the likelihood that the respective area relates to a specific structure. Further the present invention relates to a method of steering an agricultural vehicle or implement in relation to a structure in a field, and to an agricultural vehicle comprising a steering system providing steering signals, said steering system comprising an imaging device for imaging surroundings of the vehicle and an image processing device.

**[0002]** Within agriculture many processes are performed on a field whereby an implement is driven in the field back and forth or around and around to cover the entire field, e.g. when ploughing, sowing or drilling, harvesting and collecting crops. In many of these processes a track is followed, said track being provided by different areas of the field exhibiting different structure with different visual texture. The different structures may e.g. be ploughed and unploughed soil, sown and non-sown areas, drilled rows and a harrowed seedbed, standing crop and lying crop or harvested ground, swaths of cut crop and harvested ground, etc.

**[0003]** It is a wish to be able to automate the steering of the implement and the vehicle carrying or towing the implement, and many methods are being explored for identifying tracks to be follow, like the tracks mentioned above. Such methods include methods using laser scanners, photogrammetry, etc. These methods may be combined with other methods for navigating an agricultural vehicle, such as methods based on GPS, odometry, etc.

**[0004]** Methods using photogrammetry include methods using stereo-photogrammetry e.g. for detecting a three-dimensional structure on the field. Such structure could be a swath of harvested crop lying on the field to be pick-up e.g. by a baler. Such stereo-photogrammetry method is e.g. known from WO-A-2007/031093, which relates to a method of controlling a baler based on 3D imaging technology.

**[0005]** Alternative or supplementary to stereo-photogrammetry an image of the field may be analysed to distinguish the different structures e.g. by their (visual) texture. By texture should be understood local variations due to differences in colour, structure, such as straws standing or lying, being long or short, soil broken into smaller or larger lumps, etc.

**[0006]** Examples of methods using analysis of texture for distinguishing structures in an agricultural field are known, e.g.:

US 6 336 051 discloses tracking a crop line between cut and uncut crop in a field or between a processed and an unprocessed surface of the field by analysing an image of the field by scanning the pixels of a part of the image line by line and assigning by means of a colour or a texture discriminator a value to the respective pixels. For each line a step function is fitted to determine the position of the crop line, where by a binary signal is outputted. For each line the step function thus established is compared to a predetermined step function and if the established step function is outside limits the line is labelled "after end of row", otherwise the line is labelled "before end of row". By counting from the top of the image an end-of-row position is established. Further a combined probability density function for processed and unprocessed surface is provided and for regions of 10x10 pixels the probability of the region belonging to the processed or unprocessed surface of the field is calculated. If the probability falls below a threshold value the region is assumed to represent an obstacle.

**[0007]** US 7 400 957 discloses a method of detecting a structure in a field as mentioned above in the opening paragraph. More specifically it discloses detection of a swath of cut crop lying on a field by analysing an image, whereby pixel by pixel of the image is appointed a likelihood value based on the surrounding texture, the pixels are appointed the value swath or not swath according to a threshold value for the likelihood, thus providing a binary information whether the particular pixels are to be assigned to the swath of cut crop or not. The binary image thus provided is treated to reduce noise and the position and axes of inertia of the swath are established as a basis for providing a steering signal for a vehicle carrying the camera providing the image.

**[0008]** It is the object of the present invention to provide an improved method using texture information in an image for detecting a structure in a field.

**[0009]** It is a further object to provide a method of steering an agricultural vehicle or an agricultural implement carried or towed by the vehicle using the improved method using texture information.

**[0010]** It is a further object to provide an agricultural vehicle comprising a steering system providing steering signals using the improved method using texture information.

**[0011]** In a first aspect the object is fulfilled according to the invention by a method of detecting a structure in a field, said method being characterized by assuming at least one geometric property of said specific structure, and establishing a most possible position parameter of said specific structure taking into account said probability-values and the assumed geometric property. Hereby is obtained that a loss of information due to binarisation is avoided and that a position parameter of the specific structure may be established even if the signal is weak or poor.

**[0012]** The image is preferably provided in a computer readable form such as a pixel data file and each area of the plurality of areas of the image may be a group of pixels or preferably a single pixel. The plurality of areas may e.g. be

every pixel of the image or a number of mutually spaced pixels of the image.

**[0013]** Working in a field it will usually be obvious what kind of structure will be detected and accordingly the kind of geometric property may be selected. Thus the at least one geometric property is preferably selected from a group comprising a borderline, a centreline, a width, a position and an attitude. When e.g. ploughing a field a borderline between newly ploughed soil and not yet ploughed soil will be present, and when harvesting a field a borderline between harvested and not yet harvested field surface will be present. When e.g. collecting and baling swaths of previously mowed material such swaths will have a centreline and a width and they will exhibit a position or off-set relative to the current track of the vehicle used for processing the field and the direction. of extension of the centreline will have an attitude or angle relative to the current track or direction of heading of the vehicle used for processing the field.

**[0014]** Preferably the plurality of areas is assigned probability-values reflecting the likelihood that the respective areas relate to a structure different from said specific structure. Hereby is obtained an improved detection of the specific structure as the probability that respective areas do not relate to the specific structure is evaluated. Hereby the probability-values may be relative values i.e. values reflecting the probability that a given area relates to the specific structure compared to the probability that the given area relates to another structure than said specific structure.

**[0015]** Having established a most possible position parameter, e.g. the position and attitude of a borderline or of a centre line the method preferably comprises establishing a probability-value reflecting the likelihood of said specific structure being present in the image. Such probability-value may be used to evaluate the reliability of the detection, which in turn may be used for selecting a steering strategy in case of more navigation sensors being provided.

**[0016]** Prior to the step of analysing the image to obtain texture information preferably a learning or training step is performed to obtain information about texture of said structure in the field and information about texture of the field beside said structure. This learning step may be performed once for the kind of field to be processed and kind of structure expected to be found, but preferably it is performed from time to time while processing the field in question.

**[0017]** The learning step may be performed by providing an image of the field, determining areas of the image showing the structure and areas of the image showing the field beside the structure, and analysing the respective areas of the picture to obtain texture information relating to the structure and the field beside the structure, respectively.

**[0018]** Preferably an upper part and a lower part of the image are analysed individually when obtaining texture information. This is due to the fact that usually the part of the field shown in the upper part of the picture will be further away from the imaging device than the part of the field shown in the lower part of the image. This difference of distance entails a difference of visual texture due to the perspective of the image though similar structure is shown in the upper and lower part of the image. Preferably the image is thus divided into two parts i.e. an upper and a lower part, but alternatively the image may be divided into three, four or even more parts showing parts of the field in different ranges of distance.

**[0019]** According to a second aspect of the invention a method of steering an agricultural vehicle or implement in relation to a structure in a field, is characterized by detecting the structure by a method comprising: providing an image of the field, analysing the image to obtain texture information, assigning to a plurality of areas of the image probability-values reflecting the likelihood that the respective area relates to a specific structure, assuming at least one geometric property of said specific structure, and establishing a most possible position parameter of said specific structure taking into account said probability-values and the assumed geometric property; and providing a steering signal in accordance with the position parameter thus established. Hereby the advantages mentioned above in relation to the first aspect are correspondingly obtained.

**[0020]** According to a third aspect of the invention an agricultural vehicle comprising a steering system providing steering signals, said steering system comprising an imaging device for imaging surroundings of the vehicle and an image processing device, said steering system operating to provide by means of the imaging device an image of the field, analyse the image to obtain texture information, assign to a plurality of areas of the image probability-values reflecting the likelihood that the respective area relates to a specific structure, assume at least one geometric property of said specific structure, and establish a most possible position parameter of said specific structure taking into account said probability-values and the assumed geometric property; and to provide a steering signal in accordance with the position parameter thus established. Hereby the advantages mentioned above in relation to the first aspect are correspondingly obtained.

**[0021]** Preferably the steering system comprises at least one additional navigation sensor, and the steering system preferably operates taking into account an output of said additional navigation sensor when providing a steering signal. The at least one additional navigation sensor is preferably selected from a group comprising a GPS-sensor, an optical field contour sensor, an inertial measuring unit and an odometry sensor. An optical field contour sensor could e.g. comprise a laser scanning device or a 3D-imaging device such as a stereo camera. An odometry sensor could e.g. comprise wheel odometry sensors or a visual odometry sensor sensing the movement of the vehicle relative to the surroundings by image analysis as disclosed in EP application No. 08 158 693.5 (not yet published).

**[0022]** In an embodiment in which the steering system is adapted to establish a probability-value reflecting the likelihood of a specific structure being present in a image once a most possible position parameter of such structure has been established, e.g. the position and attitude of borderline or of a centre line the method preferably, such probability-value

is preferably used to evaluate the reliability of the detection, which in turn is used for selecting a steering strategy in case of more navigation sensors being provided. The principle of such selection of a steering strategy or a sensor signal processing algorithm is disclosed e.g. in EP 2 020 168 A1.

**[0023]** In the following the invention will be explained in further detail by way of examples in relation to tracking a swath in a field with reference to the accompanying drawings, in which

Fig. 1 shows a top view of a tractor and a baler hitched thereto,  
 Fig. 1a shows a cross-section of a swath shown in Fig. 1,  
 Fig. 1b shows an image provided by a camera of the tractor in Fig. 1,  
 Fig. 2 shows a top view of the tractor of Fig. 1 in another situation,  
 Fig. 2a shows an image provided by a camera of the tractor in Fig. 2,  
 Fig. 3 shows a side view of the tractor of Fig. 1 omitting the baler,  
 Fig. 4 illustrates an embodiment of a control system of the tractor of Fig. 1, and  
 Fig. 5a and 5b normalized average texture histograms.

**[0024]** Figs. 1 and 2 show a baler 1 coupled to a towing tractor 2. The baler 1 has wheels 3, a pick-up 4, a tongue 5 and a compression chamber not shown in detail. The tractor 2 has an operator's cab 6, rear wheels 7, front wheels 8 turnable by means of a hydraulic cylinder 9, and a coupling device 10 for fastening of the tongue 5 of the baler. At the very front of the tractor, an imaging device 11 is mounted. The imaging device 11 e.g. comprises a stereo camera with a signal processor for providing 3D images and colour images.

**[0025]** The imaging device 11 records images of a crop string 12 of hay/straw/grass, i.e. a swath or a windrow, in front of the tractor, which is to be picked up by the baler.

**[0026]** The tractor 2 is equipped with electro-hydraulic control with a processor 13, the hydraulic cylinder 9 and a terminal 14 with a monitor for communication with the user. The tractor has another processor 15 for controlling and monitoring various functions in the tractor, such as safety functions, and sensors for, for example, speed measurement and wheel position measurement and global positioning using GPS signals.

**[0027]** The baler 1 is equipped with a processor 19 monitoring its functions.

**[0028]** All sensors, processors or ECU's (electronic control units) 3, 15, 19 and imaging device 11 are directly or indirectly connected via a CAN network 20 for communication between such units.

**[0029]** In order to be able to control the tractor 2 and the baler 1 for optimal pick up of the crop string 12 it is important to establish the position of the crop string 12. This may be done by means of a 3D imaging device such as a stereo camera as disclosed in WO-A-2007/031093, which is also mentioned in the opening part of the present description. To this end the imaging device 11 comprises a stereo camera and images an area 21 of the field in front of the tractor 2. From the image thus taken the profile 23 of the field and the crop string 12 lying thereon may be established for a section 21' as shown in Fig. 1a. Establishing the profile 23 for successive sections from nearest the tractor 2 to farthest away the outlines 24 of the crop string 12 in the image may be established as shown in Fig. 1b. Having established the outlines 24 mutually parallel mean-outlines 25 may be calculated together with a mean width  $d$  of the crop string 12 and a mean centre line  $l$  thereof. The establishment of the profile 23 of the crop string 12 is most reliable in the range of the image near the tractor 2. Thus the range in front of the tractor, in which a reliable indication of the position of the crop string is obtainable, is limited.

**[0030]** In order to provide further information about the position of the crop string 12 and to be able to establish a more reliable estimate in a further range, the crop string is identified according to the present invention also by means of texture analysis.

**[0031]** Thus the imaging device 11, apart from the stereo image, provides an image with colour information, which is analysed, as will be explained in more detail below.

**[0032]** To be able to identify the crop string and to distinguish it from the field adjacent the crop string the control system must have information about the texture of these different parts. In the present embodiment this is obtained by performing a learning or training step, by which a plurality of areas 26 (Fig. 1b) or image patches of the part of an image (training image) depicting the crop string 12 are analysed to provide texture information, and a plurality of areas 27 or image patches of the part of the image depicting the field adjacent or beside the crop string are analysed to provide texture information.

**[0033]** Due to the effect of perspective similar items will show different texture when viewed at a distance than when viewed at close range. Therefore the upper and the lower half 28, 29 or section of the image are preferably processed separately with regard to the analysis for texture information. In other embodiments the image may be divided in this way into more sections than two.

**[0034]** As basis for a learning step an image like the one shown in Fig. 1b, which at least for the range close to the tractor, i.e. the lower half 29 of the image, provides a reliable outline 24 of the crop string, may be used. For the range far from the tractor, i.e. the upper part 28 of the image of Fig. 1b, texture information of the respective areas 30 may be

captured while the areas are in the upper part 28 of the image, and from a subsequent image it may be determined which of the areas 30 belong to the crop string 12 and which of the areas 30 belong to the field beside the crop string. Such subsequent image will be taken at a time when the tractor 2 has advanced a distance 29' (Fig. 3) corresponding to the height of the lower half 29 of the image. It should be understood that techniques for tracking positions of points or areas from one picture to another picture, which is partly overlapping the first picture, are available to the skilled person.

[0035] Having thus obtained texture information about different areas belonging to a structure in the field, i.e. the crop string, and about different areas not belonging to the structure, respectively, and at different distances, it is now possible to take a picture, i.e. to provide an image of the crop string 12' in the field as shown in Fig. 2a, analyse a plurality of areas 31 of the image and provide for the respective areas a probability value whether they depict the crop string 12' or the field beside the crop string.

[0036] It should be understood that though a few distinct areas 31 or image patches are shown in Fig. 2a, a large number of such areas 31 might be analysed and even overlapping areas. Thus an area centred round every single pixel of an image may be analysed, and preferably is.

[0037] Assuming now that the crop string 12' has a width  $d$  as determined in relation to the analysis of the image shown in Fig. 1b, the most probable position of outlines 32 of the crop string 12' are established following which an offset  $O$  and an angle or attitude  $\Theta$  of a centre line 33 of the crop string 12' relative to a centre line 34 of the tractor 2 may be established.

[0038] The offset  $O$  and the attitude  $\Theta$  may be used for establishing the need for a steering correction for the tractor 2 or the baler 1 and accordingly for the provision of a steering signal.

[0039] Since probability values are provided for the respective areas of the image, from which the offset  $O$  and the attitude  $\Theta$  are established, it is possible to evaluate the reliability of the signal, i.e. the values of the offset  $O$  and the attitude  $\Theta$ , provided. This evaluation may be used for determining how to depend on the signal of the texture analysis e.g. in case of signals from more navigation sensors, such as the signal from the stereo camera, being present.

[0040] In more details the analysis outlined above may be carried out as follows.

[0041] The image shown in Fig. 1b is in the present embodiment an image comprising pixels each defining a three dimensional colour vector  $(L_c, a_c, b_c)$  where  $L$  is intensity and  $a$  and  $b$  are two different colours.

[0042] For each pixel a descriptor  $p_i$  is defined:

$$p_i = \begin{bmatrix} W_1 * L_c \\ W_2 * a_c \\ W_2 * b_c \\ W_3 * (L_1 - L_c) \\ \vdots \\ W_3 * (L_8 - L_c) \end{bmatrix}$$

where  $(L_1 - L_c), \dots, (L_8 - L_c)$  are the intensity differences between the current pixel and the 8 surrounding pixels in a 3 X 3 neighbourhood. The vector elements are weighted using  $W_1 = 0.5$ ,  $W_2 = 1$  and  $W_3 = 0.5$ . A K-means algorithm is run on all these descriptors to extract 23 cluster centres, which are referred to as textons. Each pixel in the image is then classified as belonging to a texton by finding the nearest texton in Euclidian space. The number 23 of the cluster centres is chosen arbitrarily as a compromise between quality and speed of calculation.

[0043] As mentioned above the upper and lower half of the image of Fig. 1b are analysed separately. As an example the present explanation refers to the analysis of the lower part of the image.

[0044] Texture information is provided in a training or learning step as follows: The pixels of the image of (the lower part of) Fig. 1b (the training image) are grouped in two groups, namely "swath" and "no swath", respectively, "swath" being a group comprising pixels, which according to the outlines 24 provided by means of the 3D image depict the crop string 12, and "no swath" being a group comprising pixels, which according to the outlines 24 provided by means of the 3D image depict the field beside the crop string 12 outside its outlines 24.

[0045] Normalized average histograms or mean histograms of texton occurrences in 32 X 32 pixels image patches for the "swath" and the "no swath" case are constructed for each pixel location. These are illustrated in Fig. 5a and Fig. 5b, respectively. The histograms are clearly different in the two cases, e.g. texton #2 occurs a lot for the "swath" case and little for the "no swath" case.

[0046] As a simplification covariances of the histograms are modelled individually as Gaussian for the two cases.

[0047] These histograms thus constitute texture information obtained by the learning or training step.

[0048] To detect a structure, such as a swath, in a field steps may be performed as follows:

Given an image of a field like the image of Fig. 2a it is to be evaluated whether respective areas 31 or image patches depicts a crop string/"swath" or the field beside the crop string/"no swath".

[0049] Two hypothesis are constructed for test:

$$H_0: x[n] = s_0[n] + w_0[n] \quad n = 0, 1, \dots, N-1$$

$$H_1: x[n] = s_1[n] + w_1[n] \quad n = 0, 1, \dots, N-1$$

[0050]  $H_0$  being the hypothesis of "swath", and  $H_1$  being the hypothesis of "no swath".  $N$  is the number of textons or cluster centres, i.e. 23 in the present embodiment.  $x[n]$  is the texton histogram of the respective area 31.  $s_0[n]$ ,  $s_1[n]$  are the mean texton histograms for the two hypotheses.  $w_0[n]$ ,  $w_1[n]$  are WGN (White Gaussian Noise) taken from  $N(0, C_0)$  and  $N(0, C_1)$ , i.e. the normal or Gaussian distribution around mean = 0 with covariances  $C_0$  and  $C_1$ , respectively.  $s_0[n]$ ,  $w_0[n]$ ,  $s_1[n]$ ,  $w_1[n]$  are assumed known and calculated from the training image.

[0051] The two hypotheses are tested against each other using a Likelihood ratio test (LRT).

[0052] Probability density functions (PDF's) are conditioned on  $H_0$  and  $H_1$  as:

$$p(x; H_1) = \frac{1}{(2\pi)^{N/2} \det^{1/2}(C_1)} \exp \left[ -\frac{1}{2} (x - s_1)^T C_1^{-1} (x - s_1) \right]$$

$$p(x; H_0) = \frac{1}{(2\pi)^{N/2} \det^{1/2}(C_0)} \exp \left[ -\frac{1}{2} (x - s_0)^T C_0^{-1} (x - s_0) \right]$$

[0053] It is noted that  $p(x; H_0)$  is a probability-value reflecting the likelihood that the respective area or image patch relates to the swath, and  $p(x; H_1)$  is a probability-value reflecting the likelihood that the respective area or image patch relates to a structure different from the swath, i.e. the field adjacent the swath.

[0054] Thus LRT becomes:

$$\frac{p(x; H_1)}{p(x; H_0)} = \frac{\frac{1}{(2\pi)^{N/2} \det^{1/2}(C_1)} \exp \left[ -\frac{1}{2} (x - s_1)^T C_1^{-1} (x - s_1) \right]}{\frac{1}{(2\pi)^{N/2} \det^{1/2}(C_0)} \exp \left[ -\frac{1}{2} (x - s_0)^T C_0^{-1} (x - s_0) \right]} > \gamma$$

[0055] Taking logarithm on both sides yields:

$$\ln \left[ \frac{\frac{1}{(2\pi)^{N/2} \det^{1/2}(C_1)} \exp \left[ -\frac{1}{2} (x - s_1)^T C_1^{-1} (x - s_1) \right]}{\frac{1}{(2\pi)^{N/2} \det^{1/2}(C_0)} \exp \left[ -\frac{1}{2} (x - s_0)^T C_0^{-1} (x - s_0) \right]} \right] > \ln \gamma$$

[0056] This can be simplified yielding the LRT detector:

$$T(x) = 2x^T C_1^{-1} s_1 - x^T C_1^{-1} x - 2x^T C_0^{-1} s_0 + x^T C_0^{-1} x > \gamma'$$

$$\gamma' = 2 \ln \gamma - K$$

Where the constant  $K$  is:

$$K = 2 \ln \left[ \sqrt{\frac{\det(C_0)}{\det(C_1)}} \right] - s_1^T C_1^{-1} s_1 + s_0^T C_0^{-1} s_0$$

$\gamma'$  is a user-defined threshold that can be used to determine whether we say  $H_0$  or  $H_1$ . Instead of binarising the image using the output of the test, the raw values are used:

$$T'(x) = 2x^T C_1^{-1} s_1 - x^T C_1^{-1} x - 2x^T C_0^{-1} s_0 + x^T C_0^{-1} x$$

**[0057]**  $T(x)$  thus reflects the ratio between the likelihood of the respective area 31 relating to the swath and the likelihood of the respective area 31 not relating to the swath.

**[0058]** Using geometric information about possible widths, positions, and attitudes of the crop string 12' or swath in the image it is possible to find the Maximum Likelihood Estimate (MLE) of these parameters of the swath in the image. For this purpose it is assumed that the width  $d$  of the crop string 12' is constant and known from the training image (Fig. 1b). The position and attitude of the swath is assumed to have the swath centre line 33 inside the image with the attitude  $\Theta$  of  $\pm \pi/4$  rad relative to the camera direction projected down on an estimate of the ground plane based on the camera mounting location i.e. relative to the centre line 34 of the tractor 2.

**[0059]** First the input image (Fig. 2a) is classified using the LRT without applying a threshold. A mask can then be constructed for all feasible swath parameterisations. In the present embodiment outlines 32 of the swath or crop string 12' having a mutual distance  $d$  (the width of the swath) is used as a mask. Then the MLE is formulated as the location, which has the highest average LRT score inside the mask. This can be formulated as:

$$J = \max \left[ \frac{1}{n} \sum_{i=1}^n T'(x_i) \right]$$

$$\{x_1, \dots, x_n\} = M(k)$$

**[0060]** Given that  $\{x_1, \dots, x_n\}$  are the  $32 \times 32$  texon histograms that are believed to lie on the swath given by the function  $M$  applied to the mask  $k$ , we then seek the mask that maximizes the average LRT score  $J$ , thereby establishing the most possible position and attitude of the swath centre line 33.

**[0061]** Given that a suitable mask  $k_{\max}$  has been found that has maximized  $J$ , a test is set up to identify whether there is a swath in the image. An approach would be to threshold directly on the value of  $J$ . Instead the present inventors have formulated a looser criteria that thresholds on the ratio  $\gamma''$  of the mean LRT score of  $\{x_1, \dots, x_n\}$  for  $k_{\max}$  versus the average of  $X \setminus \{x_1, \dots, x_n\}$  where  $X$  are all classified pixels in the image:



$$\frac{\frac{1}{n} \sum_{i=1}^n T'(x_i)}{\frac{1}{m} \sum_{j=b}^m T'(x_b)} > \gamma''$$

$$\{x_1, \dots, x_n\} = M(k_{max})$$

$$\{x_b, \dots, x_m\} = X \setminus M(k_{max})$$

We denote this criteria the quality ratio.

**[0062]** The quality ratio may be used for evaluating the reliability of the output of the texture analysis, which often is referred to as a signal of a texture sensor. When using more navigation sensors the reliabilities of the sensors are used for selecting a strategy for the use of the sensor outputs.

## Claims

1. A method of detecting a structure in a field, said method comprising:
  - providing an image of the field,
  - analysing the image to obtain texture information,
  - assigning to a plurality of areas of the image probability-values reflecting the likelihood that the respective area relates to a specific structure, **characterized by**
    - assuming at least one geometric property of said specific structure, and
    - establishing a most possible position parameter of said specific structure taking into account said probability-values and the assumed geometric property and whereby at least during learning or training step the image of the field is divided in upper section 28 and a lower section 29 and both sections 28, 29 will be analysed separately.
2. A method of detecting a structure in a field according to claim 1, wherein the at least one geometric property is selected from a group comprising a borderline, a centreline, a width, a position and an attitude.
3. A method of detecting a structure in a field according to claim 1 or claim 2, wherein the plurality of areas is assigned probability-values reflecting the likelihood that the respective areas relates to a structure different from said specific structure.
4. A method of detecting a structure in a field according to claim 3, wherein the probability-values are relative values.
5. A method of detecting a structure in a field according to any of the preceding claims, wherein a probability-value reflecting the likelihood of said specific structure being present in the image is established.
6. A method of detecting a structure in a field according to any of the preceding claims, wherein prior to the step of analysing the image to obtain texture information a learning step is performed to obtain information about texture of said structure in the field and information about texture of the field beside said structure.
7. A method of detecting a structure in a field according to any of the preceding claims, wherein an upper part and a lower part of said image are analysed individually to obtain texture information.
8. A method of steering an agricultural vehicle or implement in relation to a structure in a field, **characterized by** detecting the structure by a method comprising: providing an image of the field, analysing the image to obtain texture information, assigning to a plurality of areas of the image probability-values reflecting the likelihood that the respective area relates to a specific structure, assuming at least one geometric property of said specific structure, and establishing a most possible position parameter of said specific structure taking into account said probability-values and

the assumed geometric property; and whereby at least during learning or training step the image of the field is divided in upper section 28 and a lower section 29 and both sections 28, 29 will be analysed separately and providing a steering signal in accordance with the position parameter thus established.

9. A method of steering an agricultural vehicle or implement in accordance with claim 8, wherein the at least one geometric property is selected from a borderline, a centreline, a width, a position and an attitude.
10. A method of steering an agricultural vehicle or implement in accordance with claim 8 or claim 9, wherein the plurality of areas is assigned probability-values reflecting the likelihood that the respective areas relates to a structure different from said specific structure.
11. A method of steering an agricultural vehicle or implement in accordance with claim 10, wherein the probability-values are relative values.
12. A method of steering an agricultural vehicle or implement in accordance with any of the claims 8 to 11, wherein a probability-value reflecting the likelihood of said specific structure being present in the image is established, the latter probability-value being taken into account when providing the steering signal.
13. An agricultural vehicle comprising a steering system providing steering signals, said steering system comprising an imaging device for imaging surroundings of the vehicle and an image processing device, said steering system operating to provide by means of the imaging device an image of the field, analyse the image to obtain texture information, assign to a plurality of areas of the image probability-values reflecting the likelihood that the respective area relates to a specific structure, assume at least one geometric property of said specific structure, and establish a most possible position parameter of said specific structure taking into account said probability-values and the assumed geometric property; and whereby at least during learning or training step the image of the field is divided in upper section 28 and a lower section 29 and both sections 28, 29 will be analysed separately and providing a steering signal in accordance with the position parameter thus established.
14. An agricultural vehicle according to claim 13, wherein the steering system comprises at least one additional navigation sensor, and the steering system operates taking into account an output of said additional navigation sensor when providing a steering signal.
15. An agricultural vehicle according to claim 14, wherein the at least one additional navigation sensor is selected from a group comprising a GPS-sensor, a optical field contour sensor, an inertial measuring unit and an odometry sensor.

## Patentansprüche

1. Verfahren zur Detektion einer Struktur in einem Feld, wobei das Verfahren Folgendes umfasst:

Bereitstellung eines Bildes des Feldes,  
 Analysieren des Bildes, um Texturinformation zu erhalten,  
 Zuordnen von Wahrscheinlichkeitswerten, welche die Wahrscheinlichkeit zeigen, dass der jeweilige Bereich mit einer spezifischen Struktur zusammenhängt, zu mehreren Bereichen des Bildes,  
**gekennzeichnet durch**  
 die Annahme wenigstens einer geometrischen Eigenschaft der spezifischen Struktur, und  
 Einrichten eines möglichststen Positionsparameters der spezifischen Struktur unter Berücksichtigung der Wahrscheinlichkeitswerte und der angenommenen geometrischen Eigenschaft, und wobei wenigstens während des Lern- oder Trainingsschrittes das Bild des Feldes in die obere Sektion 28 und eine untere Sektion 29 unterteilt ist und beide Sektionen 28, 29, separat analysiert werden.

2. Verfahren zur Detektion einer Struktur in einem Feld nach Anspruch 1, wobei die wenigstens eine geometrische Eigenschaft ausgewählt ist aus einer Gruppe bestehend einer Grenzlinie, einer Mittellinie, einer Breite, eine Position und einer Einstellung.
3. Verfahren zur Detektion einer Struktur in einem Feld nach Anspruch 1 oder Anspruch 2, wobei den mehreren Bereichen Wahrscheinlichkeitswerte zugeordnet werden, welche die Wahrscheinlichkeit zeigen, dass die jeweiligen Bereiche mit einer Struktur zusammenhängen, die sich von der spezifischen Struktur unterscheidet.

4. Verfahren zur Detektion einer Struktur in einem Feld nach Anspruch 3, wobei die Wahrscheinlichkeitswerte Relativwerte sind.
5. Verfahren zur Detektion einer Struktur in einem Feld nach einem der vorangehenden Ansprüche, wobei ein Wahrscheinlichkeitswert erzeugt wird, der die Wahrscheinlichkeit reflektiert, dass die spezifische Struktur in dem Bild vorhanden ist.
6. Verfahren zur Detektion einer Struktur in einem Feld nach einem der vorangehenden Ansprüche, wobei vor dem Schritt des Analysierens des Bildes zum Erhalt von Texturinformation ein Lernschritt durchgeführt wird, um Informationen über die Textur der Struktur in dem Feld und Informationen über die Textur des Feldes neben der Struktur zu erhalten.
7. Verfahren zur Detektion einer Struktur in einem Feld nach einem der vorangehenden Ansprüche, wobei ein oberer Teil und ein unterer Teil des Bildes einzeln analysiert werden, um Texturinformation zu erhalten.
8. Verfahren zum Lenken eines landwirtschaftlichen Fahrzeugs oder Gerätes bezüglich einer Struktur in einem Feld, **gekennzeichnet durch** die Detektion der Struktur **durch** ein Verfahren, umfassend:

Bereitstellung eines Bildes des Feldes,  
Analysieren des Bildes, um Texturinformation zu erhalten,  
Zuordnen von Wahrscheinlichkeitswerten, welche die Wahrscheinlichkeit zeigen, dass der jeweilige Bereich mit einer spezifischen Struktur zusammenhängt, zu mehreren Bereichen des Bildes,  
**gekennzeichnet durch**  
die Annahme wenigstens einer geometrischen Eigenschaft der spezifischen Struktur, und  
Einrichten eines möglichststen Positionsparameters der spezifischen Struktur unter Berücksichtigung der Wahrscheinlichkeitswerte und der angenommenen geometrischen Eigenschaft; und wobei wenigstens während des Lern- oder Trainingsschrittes das Bild des Feldes in die obere Sektion 28 und eine untere Sektion 29 unterteilt ist und beide Sektionen 28, 29, separat analysiert werden, und Bereitstellung eines Lenksignals gemäß des auf diese Weise erhaltenen Positionsparameters.

9. Verfahren zum Lenken eines landwirtschaftlichen Fahrzeugs oder Gerätes gemäß Anspruch 8, wobei die wenigstens eine geometrische Eigenschaft ausgewählt ist aus einer Grenzlinie, einer Mittellinie, einer Breite, einer Position und einer Einstellung.
10. Verfahren zum Lenken eines landwirtschaftlichen Fahrzeugs oder Gerätes gemäß Anspruch 8 oder Anspruch 9, wobei den mehreren Bereichen Wahrscheinlichkeitswerte zugeordnet sind, welche die Wahrscheinlichkeit zeigen, dass die jeweiligen Bereiche mit einer Struktur zusammenhängen, die sich von der spezifischen Struktur unterscheidet.
11. Verfahren zum Lenken eines landwirtschaftlichen Fahrzeugs oder Gerätes gemäß Anspruch 10, wobei die Wahrscheinlichkeitswerte Relativwerte sind.
12. Verfahren zum Lenken eines landwirtschaftlichen Fahrzeugs oder Gerätes gemäß einem der Ansprüche 8 bis 11, wobei ein Wahrscheinlichkeitswert, der die Wahrscheinlichkeit zeigt, dass die spezifische Struktur, die in dem Bild vorhanden ist, errichtet ist, wobei dieser Wahrscheinlichkeitswert berücksichtigt wird, wenn das Lenksignal bereitgestellt wird.
13. Landwirtschaftliches Fahrzeug umfassend ein Lenksystem, das Lenksignale bereitstellt, wobei das Lenksystem eine Bildgebungsvorrichtung zur Erzeugung von Bildern der Umgebung des Fahrzeugs und eine Bildverarbeitungsvorrichtung umfasst, wobei das Lenksystem derart arbeitet, dass es mittels der Bildgebungsvorrichtung ein Bild des Feldes bereitstellt, das Bild analysiert, um eine Texturinformation zu erhalten, mehreren Bereichen des Bildes Wahrscheinlichkeitswerte zuordnet, welche die Wahrscheinlichkeit zeigen, dass der jeweilige Bereich mit einer spezifischen Struktur zusammenhängt, wenigstens eine geometrische Eigenschaft der speziellen Struktur annimmt, und den möglichststen Positionsparameter der spezifischen Struktur unter Berücksichtigung der Wahrscheinlichkeitswerte und der angenommenen geometrischen Eigenschaft erzeugt; und wobei wenigstens während des Lern- oder Trainingsschrittes das Bild des Feldes in eine obere Sektion 28 und eine untere Sektion 29 unterteilt wird, und beide Sektionen 28, 29 einzeln analysiert werden, und Bereitstellen eines Lenksignals gemäß des auf diese Weise erzeugten Positionsparameters.

14. Landwirtschaftliches Fahrzeug nach Anspruch 13, wobei das Lenksystem wenigstens einen zusätzlichen Navigationssensor umfasst, und das Steuersystem bei der Bereitstellung eines Lenksignals die Ausgabe des zusätzlichen Navigationssensors berücksichtigt.

15. Landwirtschaftliches Fahrzeug nach Anspruch 14, wobei der wenigstens eine zusätzliche Navigationssensor ausgewählt ist aus einer Gruppe umfassend einen GPS-Sensor, einen optischen Feldkontursensor, eine Trägheitsmessungseinheit und einen Odometriesensor.

## Revendications

1. Un procédé pour détecter une structure dans un champ, ledit procédé consistant à :

fournir une image du champ,  
analyser l'image pour obtenir une information de texture,  
assigner à une pluralité de zones de l'image des valeurs de probabilité reflétant la vraisemblance que la zone concernée a un lien avec une structure spécifique, **caractérisé en ce qu'on**  
suppose au moins une propriété géométrique de ladite structure spécifique, et on  
établit un paramètre de position aussi probable que possible de ladite structure spécifique en prenant en compte  
lesdites valeurs de probabilité et la propriété géométrique supposée, et, au moins pendant l'étape d'apprentissage ou de formation, l'image du champ étant divisée en une section supérieure 28 et une section inférieure 29, et les deux sections 28, 29 étant analysées séparément.

2. Un procédé pour détecter une structure dans un champ selon la revendication 1, dans lequel au moins une propriété géométrique est choisie parmi un groupe comprenant une ligne de démarcation, un axe médian, une largeur, une position et une attitude.

3. Un procédé pour détecter une structure dans un champ selon la revendication 1 ou la revendication 2, dans lequel à la pluralité de zones sont assignées des valeurs de probabilité reflétant la vraisemblance que les zones concernées ont un lien avec une structure différente de ladite structure spécifique.

4. Un procédé pour détecter une structure dans un champ selon la revendication 3, dans lequel les valeurs de probabilité sont des valeurs relatives.

5. Un procédé pour détecter une structure dans un champ selon l'une quelconque des revendications précédentes, dans lequel une valeur de probabilité reflétant la vraisemblance de ladite structure spécifique présente à l'image est établie.

6. Un procédé pour détecter une structure dans un champ selon l'une quelconque des revendications précédentes, dans lequel, avant l'étape d'analyse de l'image pour obtenir une information de texture, une étape d'apprentissage est réalisée pour obtenir une information sur la texture de ladite structure dans le champ et une information sur la texture du champ à côté de ladite structure.

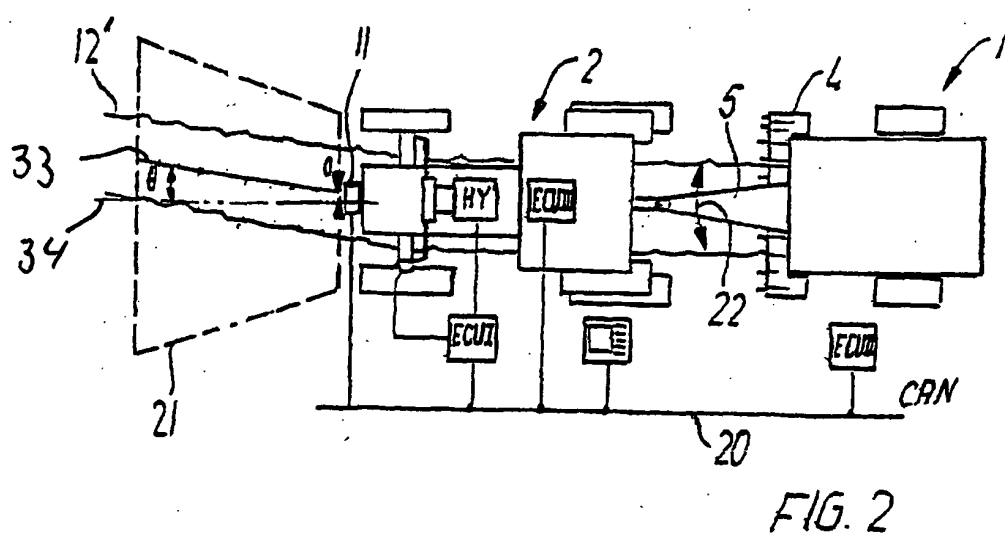
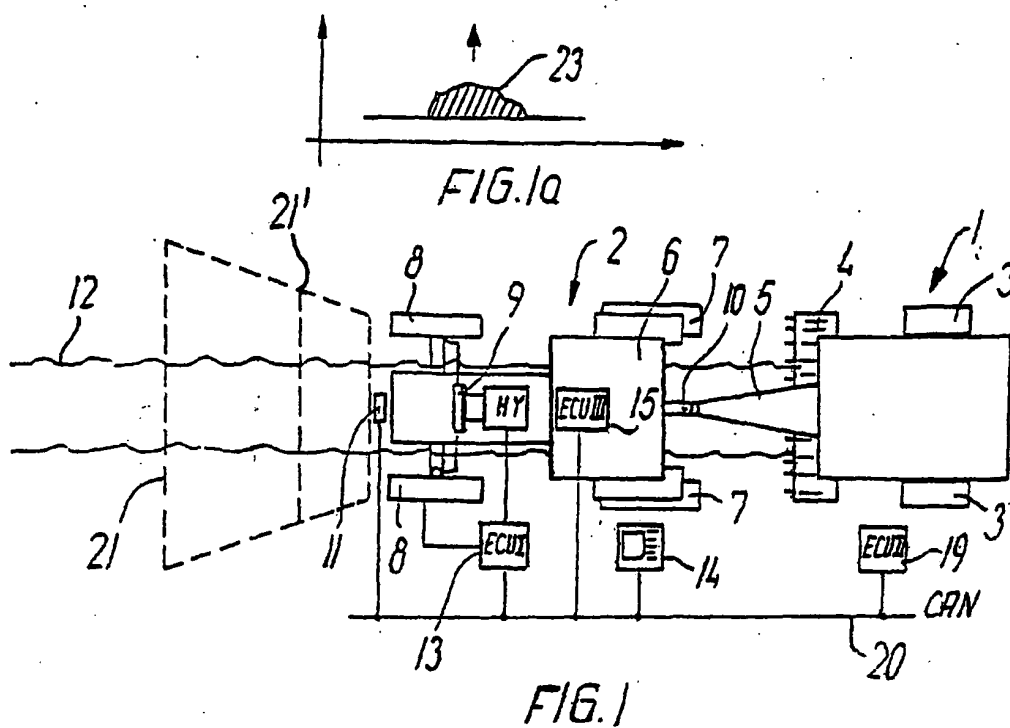
7. Un procédé pour détecter une structure dans un champ selon l'une quelconque des revendications précédentes, dans lequel une partie supérieure et une partie inférieure de ladite image sont analysées individuellement pour obtenir une information de texture.

8. Un procédé pour diriger un véhicule ou un outil agricole en fonction d'une structure dans un champ, **caractérisé en ce qu'il** consiste à détecter la structure par un procédé consistant à : fournir une image du champ, analyser l'image pour obtenir une information de texture, assigner à une pluralité de zones de l'image des valeurs de probabilité reflétant la vraisemblance que la zone concernée a un lien avec une structure spécifique, supposer au moins une propriété géométrique de ladite structure spécifique, et établir un paramètre de position aussi probable que possible de ladite structure spécifique en prenant en compte lesdites valeurs de probabilité et la propriété géométrique supposée ; et, au moins pendant l'étape d'apprentissage ou de formation, l'image du champ étant divisée en une section supérieure 28 et une section inférieure 29, et les deux sections 28, 29 étant analysées séparément, et fournir un signal de direction en fonction du paramètre de position ainsi établi.

9. Un procédé pour diriger un véhicule ou un outil agricole conformément à la revendication 8, dans lequel la au moins

une propriété géométrique est choisie parmi une ligne de démarcation, un axe médian, une largeur, une position et une attitude.

- 5 10. Un procédé pour diriger un véhicule ou un outil agricole conformément à la revendication 8 ou la revendication 9, dans lequel à la pluralité de zones sont assignées des valeurs de probabilité reflétant la vraisemblance que les zones concernées ont un lien avec une structure différente de ladite structure spécifique.
- 10 11. Un procédé pour diriger un véhicule ou un outil agricole conformément à la revendication 10, dans lequel les valeurs de probabilité sont des valeurs relatives.
- 15 12. Un procédé pour diriger un véhicule ou un outil agricole conformément à l'une quelconque des revendications 8 à 11, dans lequel une valeur de probabilité reflétant la vraisemblance de ladite structure spécifique présente à l'image est établie, la dernière valeur de probabilité étant prise en compte lors de la fourniture du signal de direction.
- 20 13. Un véhicule agricole comprenant un système de direction fournissant des signaux de direction, ledit système de direction comprenant un dispositif d'imagerie pour imager l'environnement du véhicule et un dispositif de traitement d'image, ledit système de direction opérant pour fournir au moyen du dispositif d'imagerie une image du champ, analyser l'image pour obtenir une information de texture, assigner à une pluralité de zones de l'image des valeurs de probabilité reflétant la vraisemblance que la zone concernée a un lien avec une structure spécifique, supposer au moins une propriété géométrique de ladite structure spécifique, et établir un paramètre de position aussi probable que possible de ladite structure spécifique en prenant en compte lesdites valeurs de probabilité et la propriété géométrique supposée ; et, au moins pendant l'étape d'apprentissage ou de formation, l'image du champ étant divisée en une section supérieure 28 et une section inférieure 29, et les deux sections 28, 29 étant analysées séparément, et  
25 pour fournir un signal de direction en fonction du paramètre de position ainsi établi.
- 30 14. Un véhicule agricole selon la revendication 13, dans lequel le système de direction comprend au moins un capteur de navigation supplémentaire, et le système de direction opère en prenant en compte une sortie dudit capteur de navigation supplémentaire lors de la fourniture d'un signal de direction.
- 35 15. Un véhicule agricole selon la revendication 14, dans lequel le au moins un capteur de navigation supplémentaire est choisi parmi un groupe comprenant un capteur GPS, un capteur optique de contour de champ, une unité de mesure inertielle et un capteur odométrique.



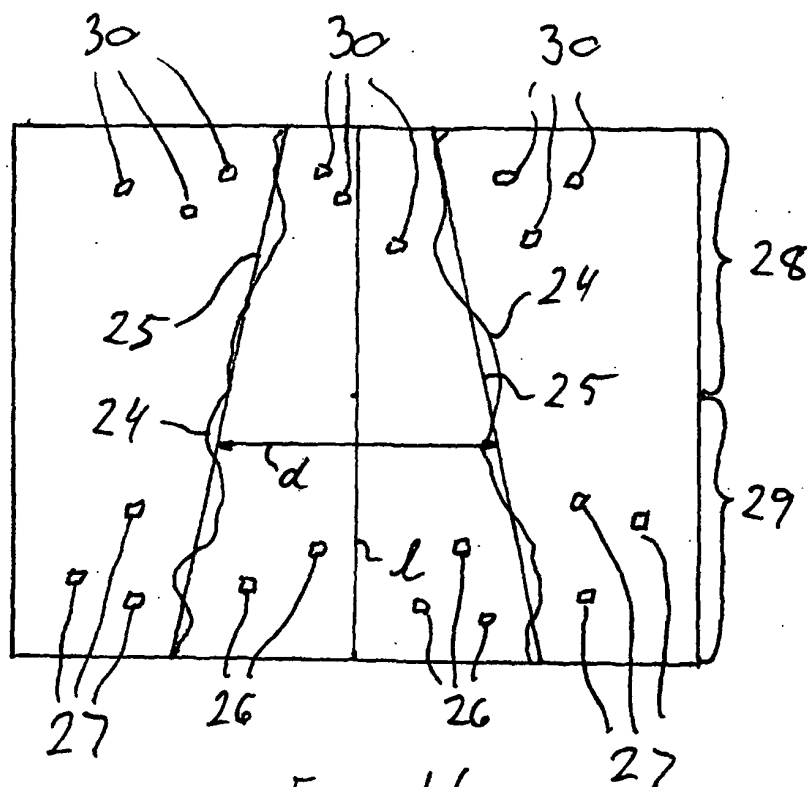


Fig 16

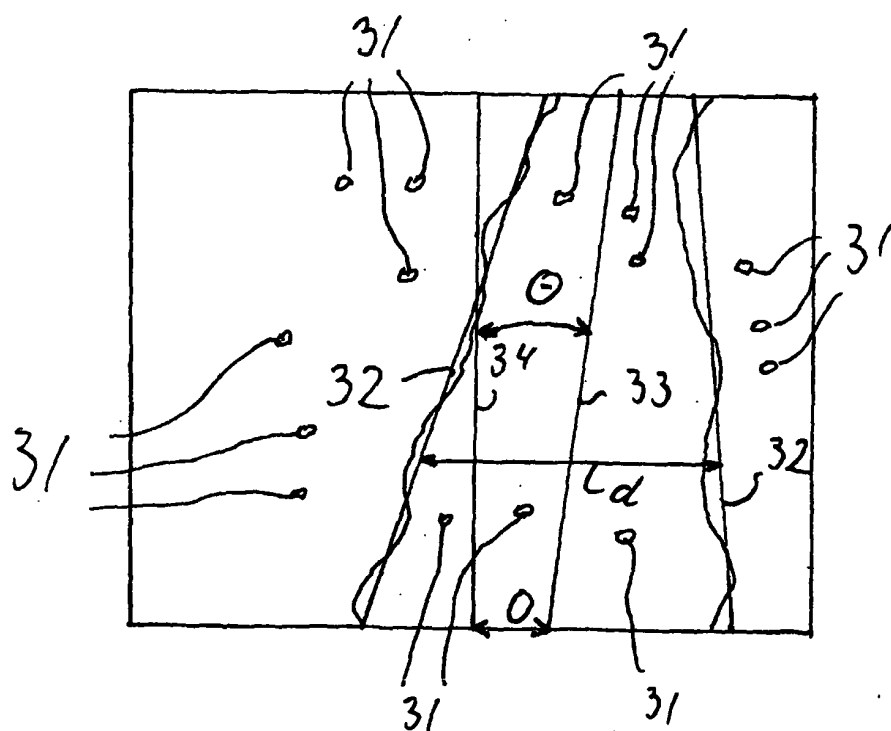
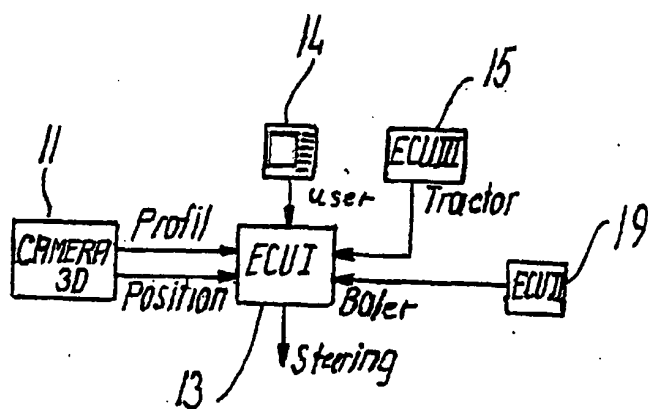
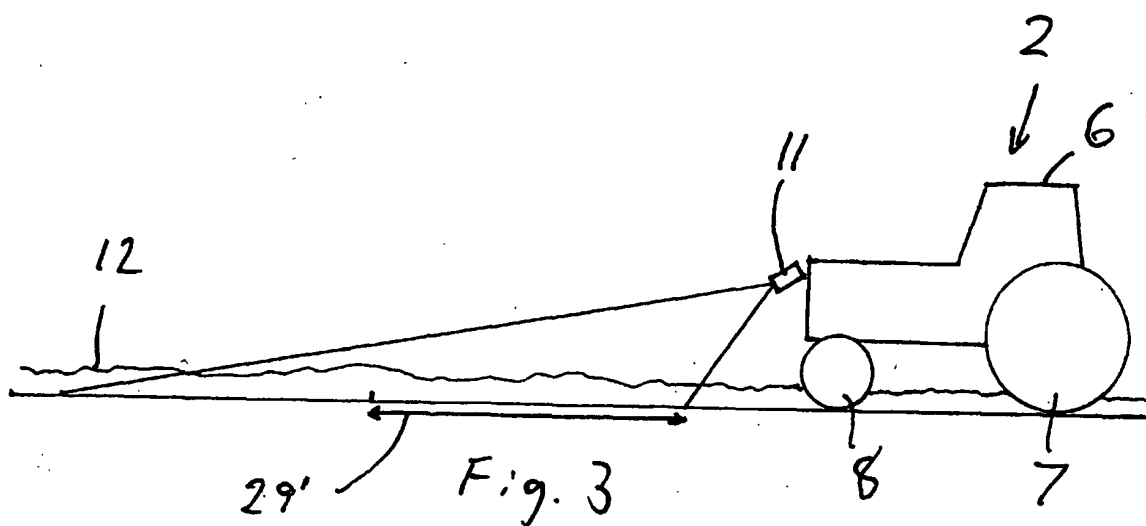


Fig 2a





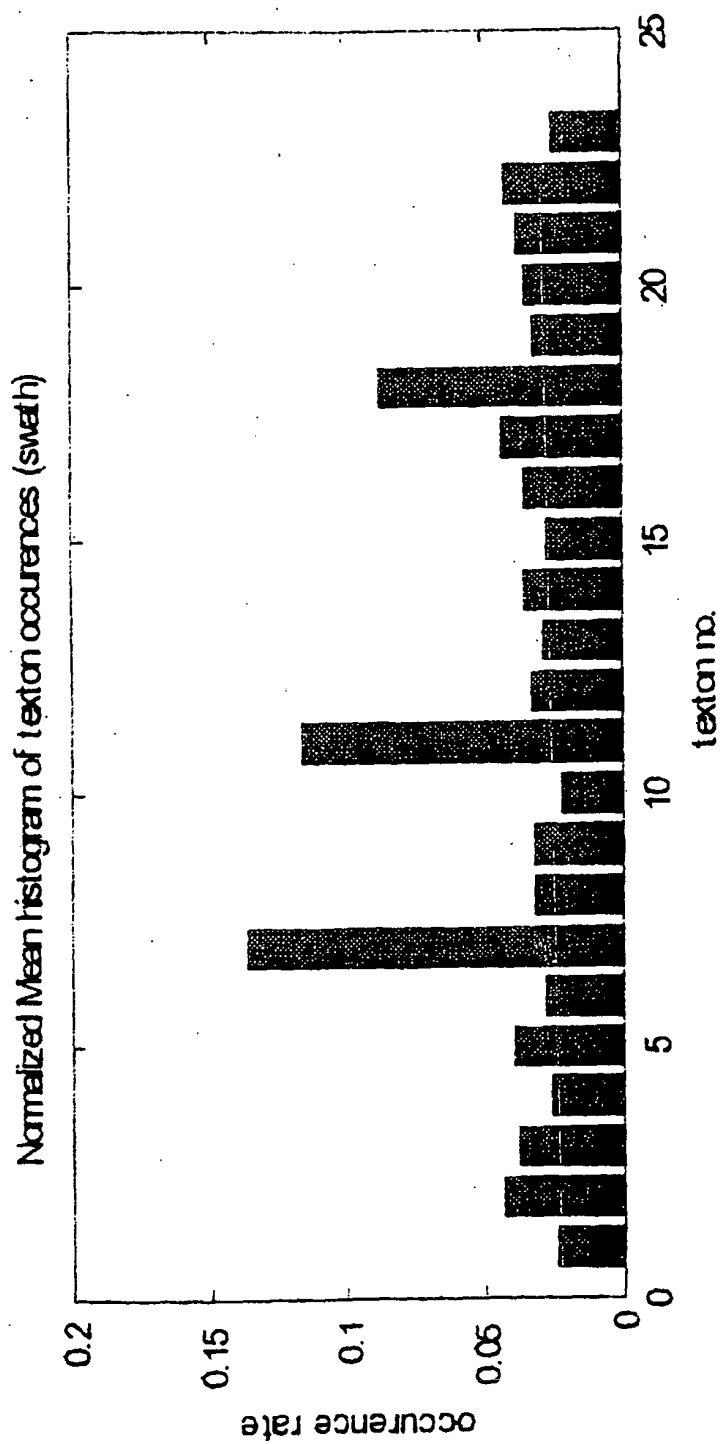


Fig. 5a

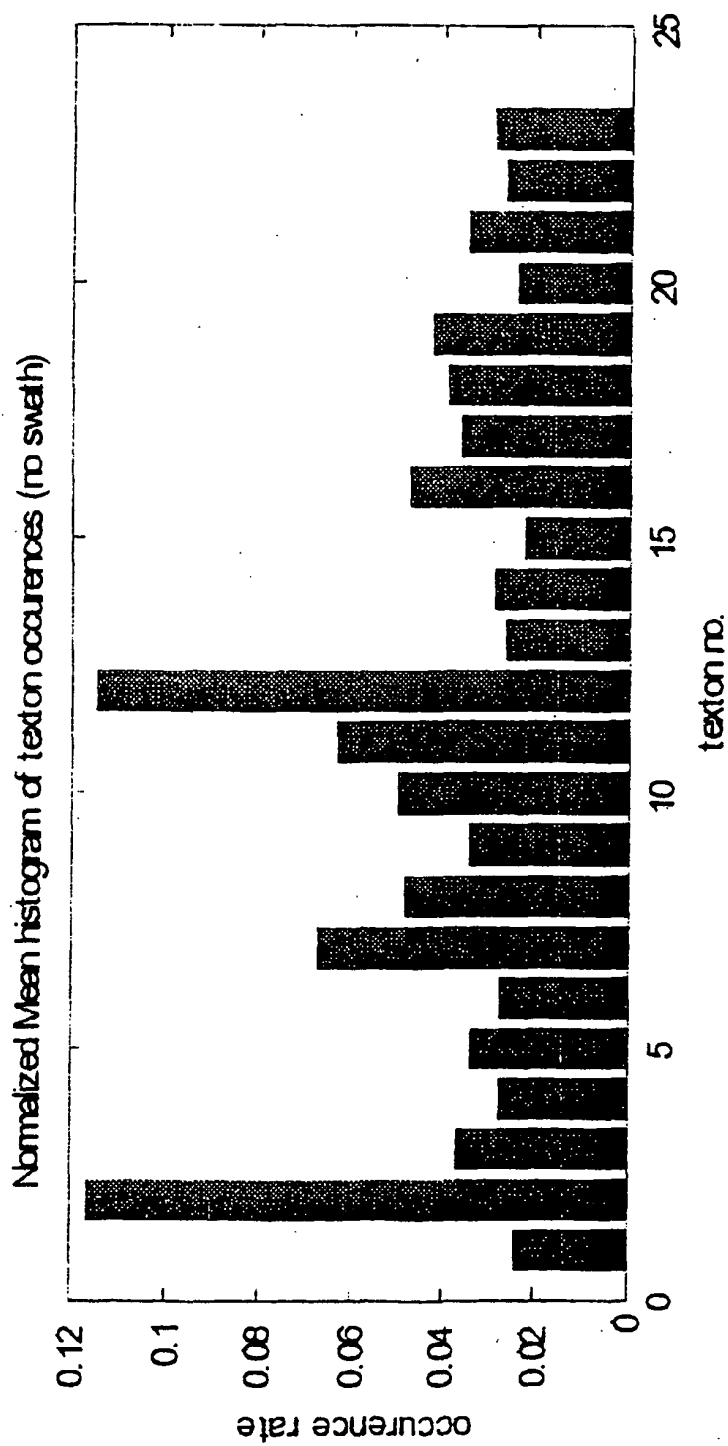


Fig. 56

**REFERENCES CITED IN THE DESCRIPTION**

*This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.*

**Patent documents cited in the description**

- WO 2007031093 A [0004] [0029]
- US 6336051 B [0006]
- US 7400957 B [0007]
- EP 08158693 A [0021]
- EP 2020168 A1 [0022]